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Role of pre-existing weakness in controlling the Cenozoic tectonic evolution of the eastern Tibetan plateau given by analogue experiments

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The Longmen Shan fold-and-thrust belt/right-slip transpressional fault belt and the Xianshuihe left-slip fault zone are the two most dominant structural systems in eastern Tibet during the India-Asia collision. How these structures were constructed has been thoroughly debated. A key parameter that was not considered in the current models is the pre-existing weakness created by protracted terrane accretion/collision of the region during the evolution of the Paleo-Tethyan orogenic systems prior to the India-Asia collision. In this study, we address this problem for the first time by examining how the older structures are responding to different plausible local boundary conditions and pre-existing weakness distribution. Specifically, we use analogue-model experiments to evaluate how the pre-Cenozoic structures may have controlled the location, orientation, and kinematics of the northwest-striking Xianshuihe fault zone and northeast-striking Longmen Shan fold-and-thrust belt. Our best model indicates that the correct location, trend, and kinematics of the two structures can only be generated and maintained if the following conditions are met: (1) the northern part of the Songpan-Ganzi terrane in eastern Tibet has a strong basement whereas its southern part has a weak basement, (2) the northern strong basement consists of two pieces bounded by a crustal-scale weak zone that is expressed by the Triassic development of a northwest-trending antiform exposing lower crustal rocks, and (3) the region was under persistent northeast-southwest compression since ~35 Ma. Our model makes correct prediction on the sequence of deformation in eastern Tibetan plateau: the Longmen Shan right-slip transpressional zone was initiated first as an instantaneous response to the northeast-southwest compression, which is followed by the formation of the Xianshuihe fault about a half way after the exertion of northeast-southwest shortening in the model. The success of our model highlights the importance of pre-existing weakness, a key factor that has been largely neglected in the current geodynamic models of continental deformation.